1   **Supplementary material for:**

2   **Lyme neuroborreliosis and bird populations in northern Europe**

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6   **Criteria for being reported as notifiable Lyme borreliosis.**

7   Lyme borreliosis in Norway are notifiable by both clinicians and medical laboratories. Only

8   cases with complete patient information get registered in the Norwegian Surveillance System

9   for Communicable Diseases (MSIS) organised by the Norwegian Institute of Public Health

10   (NIPH) [1]. The notification criteria after 1995 were as follows: A clinically compatible case

11   with laboratory confirmation of *Borrelia burgdorferi* infection is either (1) directly by aid of

12   isolation or nucleic acid test (with PCR) or (2) indirectly through immune responses and

13   detection of antibodies (IgM in serum or cerebrospinal fluid (CSF), or IgG in CSF produced

14   intrathecally or with a high concentration in serum). Early localized disease (erythema

15   migrans only) is not notifiable, while multiple erythema migrans is considered disseminated

16   disease and is notifiable. Direct detection of genetic material with PCR is done primarily on

17   synovial fluid for cases of Lyme arthritis and on biopsies from skin lesions. In addition PCR

18   is used on CSF from children. Detection of antibodies is done by ELISA, with tests including

19   VlsE peptide on serum and/or CSF, chemiluminescence assay (CLIA), or enzyme linked

20   fluorescence assay (ELFA (enzyme linked fluorescence assay), occasionally combined with

21   Western blot/line blot. To be notified as neuroborreliosis in MSIS, the result of both antibody

22   tests (white blood cells in CSF) or evidence of intrathecal production by the use of antibody

23   index (AI) is used together with clinical information, i.e. if the patient has a higher level than

24   expected of antibodies (IgG/IgM) in CSF due to diffusion over the meninges and also if

25   increased white blood cells is present is assessed together with clinical symptoms of the

26 patient since both ELISA and AI are hampered by a low sensitivity (if symptom duration <6

27 weeks) and low specificity if judged without other criteria.

28 1. MacDonald, E., Vestrheim, D. F., White, R. A., Konsmo, K., Lange, H., Aase, A.,

29 Nygård, K., Stefanoff, P., Aaberge, I. & Vold, L. 2016 Are the current

30 notification criteria for Lyme borreliosis in Norway suitable? Results of an

31 evaluation of Lyme borreliosis surveillance in Norway, 1995–2013. *BMC Public*

32 *Health* **16**, 1-11.

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36 **Table S1.** The basis for calculating the bird hazard index is data on mean *B. garinii*

37 prevalence and mean larval *Ixodes ricinus* load, which multiplies to a hazard by each species.

38 Data from [1]. The hazard index 1 and 2 is calculated by summing the hazard.

Species	*B. garinii* prevalence	Larval tick load	Hazard	Hazard index 1	Hazard index 2
Anthus trivialis	0.064	0.212	0.014		x
Erithacus rubecula	0.006	1.289	0.008		x
Fringilla coelebs	0.038	0.879	0.034		x
Parus major	0.096	0.463	0.045		x
Prunella modularis	0.004	1.090	0.004		x
Sylvia atricapilla	0.001	0.180	0.000		x
Troglodytes troglodytes	0.056	0.651	0.036		x
Turdus iliacus	0.281	0.271	0.076	x	x
Turdus merula	0.183	2.812	0.514	x	x
Turdus philomelos	0.120	1.780	0.214	x	x

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41   1.   Heylen, D., Fonville, M., Docters van Leeuwen, A., Stroo, A., Duisterwinkel, M., Van

42   Wieren, S., Diuk-Wasser, M., de Bruin, A. & Sprong, H. 2017 Pathogen

43   communities of songbird-derived ticks in Europe's low countries. *Parasite*

44   *Vector* **10**, 497.

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47   **Table S2.** Data at municipality level for the period 1995-2017, summarized by median, first and third quartiles. Detailed information of the data

48   and analyses are given in Material & Methods. Only municipalities (n=204) with at least one case of Lyme borreliosis are included.

Variable	*All data*		*East*		*South*		*West*	
	50%	(25%, 75%)	Median	(25%, 75%)	Median	(25%, 75%)	Median	(25%, 75%)
Number of Neuro cases	5	(2, 11)	2	(1, 5)	6.5	(2, 22)	5.5	(3, 11)
Number of LD cases	6	(3, 13.3)	2.5	(1, 6)	9.5	(3, 38.3)	7.5	(3, 12)
Mean inhabitants (100)	67	(31, 139)	142	(90, 267)	65	(31, 119)	48	(29, 95)
Hazard index 1 (lag 1)	48.4	(33.0, 62.5)						
Hazard index 2 (lag 1)	51.1	(36.5, 65.7)						
Winter NAO (lag 1)	0.27	(-0.39, 1.09)						
Distance to fjord (km)	41	(18, 144)	133	(40, 374)	99	(34, 249)	29	(8, 50)
Mean deer density	1.04	(0.69, 1.49)	1.22	(0.75, 1.72)	1.01	(0.68, 1.56)	0.97	(0.69, 1.35)
Human settlement	0.01	(0.002, 0.02)	0.02	(0.01, 0.06)	0.01	(0.002, 0.02)	0.004	(0.001, 0.02)
Agricultural area	0.06	(0.03, 0.12)	0.11	(0.08, 0.22)	0.04	(0.02, 0.08)	0.05	(0.03, 0.09)
Area above 200 m.a.s.l.	0.51	(0.10, 0.83)	0.29	(0.01, 0.65)	0.46	(0.08, 0.74)	0.54	(0.25, 0.87)

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Table S3. An overview of studies reporting the composition (%) of *B. burgdorferi* sl genospecies in questing nymphs in Norway. n = number of

infected nymphs.

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Area	Year	n	*B. afzelii*	*B. garinii*	*B. burgdorferi* ss	*B. valaisiania*	Ref.
Sogn & Fjordane county	2009-16	146	67	26	0.7	6	[3]
Møre & Romsdal county	2011, 13	98	80	16	0	4	[3]
Skodje, Møre & Romsdal	2010-12	288	67.9	20.7	3.79	7.59	[4]
Farsund, Vest-Agder	2007	122	88.5	5.7	4.9	0.8	[2]
Mandal, Vest-Agder	2007	100	28	50	13	9	[2]
Søgne, Vest-Agder	2007	88	54.5	23.9	14.8	5.7	[2]
Tromøy, Aust-Agder	2007	88	69.3	17	11.4	2.3	[2]
Oslofjorden, several locations[*]	2012-13	73	86	12	0	1.4	[1]

[*] Hille, Mandal, Vest-Agder county; Tromøy, Arendal, Aust-Agder county; Brønnøya, Asker, Akershus county; Spjærøy, Hvaler, Østfold county)

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References

1. Kjelland, V., Paulsen, K. M., Rollum, R., Jenkins, A., Stuen, S., Soleng, A., Edgar, K. S., Lindstedt, H. H., Vaino, K., Gibory, M. & Andreassen, Å. K. 2018 Tick-borne encephalitis virus, *Borrelia burgdorferi* sensu lato, *Borrelia miyamotoi*, *Anaplasma phagocytophilum* and *Candidatus* Neoehrlichia mikurensis in *Ixodes ricinus* ticks collected from recreational islands in southern Norway. *Ticks Tick Borne Dis* **9**, 1098-1102.

64   2. Kjelland, V., Stuen, S., Skarpaas, T. & Slettan, A. 2010 Prevalence and genotypes of *Borrelia burgdorferi* sensu lato infection in *Ixodes*

65   *ricinus* ticks in southern Norway. *Scand J Infect Dis* **42**, 579-585.

66   3. Mysterud, A., Stigum, V. M., Jaarsma, R. & Sprong, H. 2019 Genospecies of *Borrelia burgdorferi* detected in 16 mammal species and

67   questing ticks from Norway. *Sci Rep* **9**, 5088.

68   4. Tveten, A. K. 2013 Prevalence of *Borrelia burgdorferi* sensu stricto, *Borrelia afzelii*, *Borrelia garinii*, and *Borrelia valaisiana* in *Ixodes*

69   *ricinus* ticks from the northwest of Norway. *Scand J Infect Dis* **45**, 681-687.

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72 **Table S4.** Parameter estimates for analysis (GLMM with negative binomial family) of

73 number of cases of Lyme borreliosis in Norway from 1995-2017. Population size was

74 included as an offset variable. Random effect variances of 204 municipalities nested in 14

75 counties were 0.14 and 0.06, respectively. Variables were scaled to the mean 0 and variance

76 1. Sqrt = square root. NAO=North Atlantic Oscillation index. DJF-December, January and

77 February.

Parameter	Estimate	SE	Z	P
Intercept	-10.040	0.146	-68.65	< 0.001
Log (spatial deer density + 0.1)	0.333	0.058	5.78	< 0.001
Bird *B. garinii* hazard (lag 1 yr)	0.060	0.024	2.51	0.012
Region (South vs. other)	0.478	0.218	2.19	0.028
Region (East vs. other)	-0.929	0.232	-4.00	< 0.001
Year	0.516	0.038	13.54	< 0.001
I ($year^2$)	-0.181	0.037	-4.87	< 0.001
Sqrt (distance to coast)	-0.420	0.083	-5.06	< 0.001
Sqrt (prop. human settlement)	-0.556	0.055	-10.04	< 0.001
Sqrt (agricultural area)	-0.351	0.067	-5.26	< 0.001
area > 200 m a.s.l.	-0.341	0.078	-4.38	< 0.001
Sqrt (incidence) (lag 1 yr)	0.055	0.025	2.25	0.024
NAO – DJF (lag 1 yr)	0.095	0.022	4.30	< 0.001
Year:Region (South vs. other)	-0.436	0.048	-9.12	< 0.001
I ($year^2$):Region (South vs. other)	0.175	0.050	3.53	< 0.001

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